Assessing Drilling Waste Disposal Areas: Compliance Options for Reclamation Certification

Alberta
Environment

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ONGOING COMMITMENT

Alberta Environment is committed to working with the Energy and Utilities Board, Sustainable Resource Development, and industry to ensure that guidance for drilling waste management and environmental endpoints are harmonized and drilling waste disposal areas pose no risk to the environment.

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http://www.gov.ab.ca/env/protenf/landrec/upstream/index.html

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OVERVIEW

Alberta's certification program for reclaimed upstream oil and gas facilities changed on October 1, 2003 to include stronger requirements for management of contamination, including any related to drilling waste. This document was developed by representatives from the Canadian Association of Petroleum Producers, drilling waste disposal consultants, Sustainable Resource Development, the Energy and Utilities Board, and Alberta Environment to provide guidance for assessing drilling waste disposal areas for reclamation.

To address the diversity of drilling wastes and available information types, three compliance options have been developed. All three options are intended to deliver the same environmental results, which are based mainly on the Alberta Energy and Utilities Board 1996 Directive 50: Drilling Waste Management. Each of the three options is discussed in this document and appendices are included to support technical procedures included in the options. Compliance Options One and Two exempt drilling waste disposal areas from a Phase 2 environmental site assessment (ESA). If the drilling waste disposal area does not meet the requirements specified in either of these options, a Phase 2 ESA (Compliance Option 3) must be conducted in the drilling waste disposal area.

A. BACKGROUND

1. Introduction

Drilling waste disposal has been regulated in Alberta since 1975, when the Energy Resources Conservation Board (ERCB) released the Interim Directive *ID-OG-75-2*. Interim Directive (ID) 93-1 and *Guide 50: Drilling Waste Management* superseded this document in June 1993. Then in 1996 the Alberta Energy and Utilities Board (EUB) issued a revision to *Guide 50*, which was introduced with *Information Letter (IL) 96-13: Revision of Guide 50 Drilling Waste Management*. *Guide 50* has been renamed to *Directive 50*.

Under the Upstream Oil and Gas Reclamation and Remediation Program, which came into effect on October 1, 2003, oil and gas operators are required to show compliance with Alberta Environment standards by submitting disposal information for drilling waste that was disposed of on a wellsite or at a remote sump or land treatment. This guideline harmonizes Alberta Environment requirements for drilling waste disposal areas with the 1996 *Directive 50* whenever possible.

This guideline supersedes *Assessing Drilling Waste Disposal Areas: Compliance Options for Reclamation Certification* (February 2005), effective immediately.

2. Phased Environmental Site Assessments

This guidance document describes Phase 1 ESA processes under Compliance Options One and Two, and Phase 2 ESA requirements in Compliance Option Three. Uncertainty is inherent in any Phase 1 ESA. The Canadian Standards Association states that since a Phase 1 does not involve sample collection or other intrusive investigations, "a Phase 1 ESA report can, in most cases, only describe the likelihood of contamination being present or absent at a property" (CSA 1994). A Phase 1 ESA that is performed under the requirements of the CSA Phase 1 ESA Standard will reduce, but not eliminate, uncertainty as to the potential for contamination to be present at a site. "Where this potential has been identified, the further reduction or elimination of uncertainty requires the performance of a Phase 2 ESA" (CSA 1994).

For drilling waste disposal areas, an advanced Phase 1 ESA as described in Compliance Options One and Two can form the basis for additional investigation of a site through a Phase 2 ESA. If there is insufficient information to complete a Phase 1 ESA, uncertainty will not be reduced and a Phase 2 ESA is required.

A Phase 2 ESA can be used to confirm or refute the potential contamination identified in a Phase 1 ESA, provide supplemental information for previous Phase 2 ESAs and provide the basis for evaluating site remediation needs. A Phase 2 ESA "characterization may range from a simple identification to a full delineation of the contamination on site" (CSA 2000). The Standard developed by the CSA establishes the fundamentals and practices for a Phase 2 ESA. The Standard provides a consistent framework and establishes "minimum requirements for conducting Phase 2 ESAs that can accommodate broader regulatory and liability requirements, as well as address pertinent site-specific requirements" (CSA 2000). The framework includes development of a sampling plan, preparation for and execution of an investigation that includes sampling and measuring, followed by interpretation and reporting on the information obtained.

3. Intent of Document

The intent of this document is to provide information and guidance on each of the three Compliance Options for drilling waste disposal areas to assist well licencees and reclamation practitioners in meeting Alberta Environment's requirements for the Upstream Oil and Gas Reclamation and Remediation Program. Where site audits or future events identify parameters that exceed Alberta Environment's remediation requirements, the licensee remains responsible for remediation, regardless of the results obtained from the checklists and calculations in this document.

4. Qualified People

The assessor should be objective and possess an appropriate combination of formal education, knowledge, skills and experience to conduct a technically sound assessment of the daily drilling records, Tour Reports, *Notification of Drilling Waste Disposal* form and to conduct a Phase 2 environmental site assessment (ESA), if required.

5. Reclamation of Drilling Waste Disposal Areas

The *Environmental Protection and Enhancement Act* (EPEA) requires an operator to conserve and reclaim specified land and obtain a reclamation certificate. The Conservation and Reclamation Regulation and EPEA definition of specified land includes land that is being or has been used or held for or in connection with the construction, operation or reclamation of a well, battery, oil production site, and pipeline. Land that has been used for a remote sump or land treatment is specified land.

Under the Upstream Oil and Gas Reclamation and Remediation Program, which came into effect on October 1, 2003, oil and gas operators are required to submit drilling waste disposal data for drilling waste that was disposed of within a lease or at a remote sump or land treatment area.

(a) Drilling Waste Disposal Areas

Drilling waste disposal areas include portions of the wellsite, remote sump, or land treatment area where drilling wastes have been buried, spread on land, or mixed into soil. Off-lease agricultural or forested land used for disposal of drilling waste by pump-off, landspray-while-drilling, or landspray does not require a reclamation certificate.

The *Phase 1 Environmental Site Assessment Guideline for Upstream Oil and Gas Sites* (AENV, 2001) outlines Alberta Environment's requirements for Phase 1 ESA level of effort. Occasionally, the location of remote sumps and off-site land treatment areas cannot be verified by file information. When this is the case, the assessor must be able to confirm that all the requirements of the above Phase 1 Guideline were met before declaring that the disposal location is unknown.

(b) Drilling Waste Disposal Methods

Directive 50 restricts drilling waste being managed by landspreading or mix-bury-cover to the wellsite or associated remote sump. Off-lease disposal options are landspraying, pump-off (clear liquids only) and landspraying-while-drilling (LWD). Land treatment of hydrocarbon-based or contaminated drilling waste may occur on or off the wellsite. Land treatment disposals and alternative disposal methods such as biopiles require approval from the EUB.

(c) Single and Multi-well Sumps and Land Treatment

Single well remote sumps must be reclaimed prior to or at the time when the associated wellsite is reclaimed. Multi-well remote sumps should be reclaimed with one of the wells that generated the waste, or be reclaimed independently. If a well licensee chooses to associate a multi-well remote sump with a different well than the one currently being reclaimed, they must specify which well license, including legal land description, will include the remote sump in the *Reclamation Certificate Application* form and in the comments section of the Checklist. Land treatment areas must be reclaimed when the treatment activity is complete.

(d) Drilling Fluid Systems

Drilling fluid systems typically consist of bentonite and a range of additives mixed with water or hydrocarbon. Common water based systems include relatively low salinity gel chem muds and higher salinity advanced gel chem and salt systems. Advanced gel chem systems such as *potassium sulphate, potassium silicate, sodium silicate, or potassium formate* systems have potentially high salinity associated with them. Advanced gel chem systems are defined in the EUB *Information Letter (IL) 2001-3: Management of Drilling Wastes Associated with Advanced Gel Chemical Systems*. Hydrocarbon-based systems such as invert diesel systems have high concentrations of hydrocarbons that must be managed by land treatment or an alternative disposal method as per *Directive 50* or at an approved facility subject to waste tracking, characterization, and classification requirements under *Directive 58: Oilfield Waste Management Requirements for the Upstream Petroleum Industry*, and subsequent updates to it.

A number of drilling fluid additives are used to ensure the fluid properties are compatible with the geological conditions encountered during drilling. The additives affect drilling waste characteristics such as pH, salinity, and toxicity that must be properly managed to prevent adverse environmental effects. Some additives are known to be toxic and some additives contain elevated levels of trace metals. Additional information on additives is provided within the description of each Compliance Option.

6. Compliance Options

(a) Compliance Option One

Compliance Option One requires submission of a *Notification of Drilling Waste Disposal Form* from *Directive50*, or equivalent, and the Compliance Option One Checklist (with the attached Calculation Tables, if necessary) confirming that all *Directive 50* requirements were met. Compliance Option One will not be accepted for advanced gel-chem systems as defined in EUB *Information Letter IL 2001-3* (e.g., *potassium sulphate, potassium silicate, sodium silicate, or potassium formate)* unless an EUB written approval for the disposal and documentation proving compliance with the approval conditions are submitted. If insufficient information is available to allow completion of the Compliance Option One checklist, Compliance Option Two or a Phase 2 ESA must be completed.

(b) Compliance Option Two

Compliance Option Two requires submission of the completed Compliance Option Two Checklist and Calculation Tables (attached) confirming that the specified requirements have been met. This option may be used when a *Directive 50 Notification of Drilling Waste Disposal* form is incomplete or not available, and/or an advanced gel chem drilling fluid system was used and disposed of on-site. If no information or insufficient information is available to allow

completion of either a Compliance Option One or Option Two checklist, a Phase 2 ESA must be completed.

(c) Compliance Option Three

A Phase 2 ESA of the drilling waste disposal area must be conducted if the Compliance Option One or Two Checklists cannot be completed due to insufficient information or if the available information indicates the waste does not meet the requirements for Compliance Option One or Compliance Option Two.

Each of the Compliance Options is discussed in more detail on the following pages.

B. COMPLIANCE OPTION ONE

Compliance Option One requires submission of a completed *Notification of Drilling Waste Disposal Form* from *Directive 50*, or equivalent, and the completed Compliance Option One Checklist (attached) confirming that all *Directive 50* requirements were met. If the Checklist results indicate the Calculation Tables are required, the completed tables must also be submitted.

Compliance Option One will not be accepted for advanced gel-chemical systems as defined in EUB Information Letter IL 2001-3 (e.g., *potassium sulphate, potassium silicate, sodium silicate, or potassium formate)* unless an EUB written approval for the disposal and documentation proving compliance with the approval conditions is available.

Compliance Option One applies also to landtreatment drilling waste disposal, alternative disposals such as biopiles, and disposal at an approved facility. If landtreatment or an alternative disposal method was used, the licensee must ensure that all conditions of the approval, as well as the requirements in *Directive 50* for the detailed disposal plan were met. If drilling waste was disposed at an approved waste management facility, information to verify that the waste was received at the facility must be available (e.g., invoice from the receiving facility, manifests, truck tickets, Alberta Oilfield Waste Form, or other documentation from the well file that would identify use of an approved waste management facility) must be listed as Reference Documents on the checklist. Reference documents must be submitted to Alberta Environment, if requested. If the well licensee does not have documentation confirming waste disposition, a Phase 2 ESA is required.

The Checklist and Calculation Tables will indicate if Compliance Option One is acceptable for a site or whether Compliance Option Two or a Phase 2 ESA is necessary. If the Compliance Option One Checklist cannot be completed because of insufficient information, the assessor must use Compliance Option Two or Three.

Background information is provided below to guide the completion of the Compliance Option One checklist.

1. General Disposal and Drilling Fluid Information

For Compliance Option One, a completed *Directive 50 Notification of Drilling Waste Disposal* form, or equivalent, must be reviewed using the Compliance Option One Checklist to ensure that the drilling waste disposal and drilling fluid systems were compliant with *Directive 50*.

If the cuttings associated with landspray or landspray-while-drilling were managed on the wellsite, these will often not have separate analytical information or a unique notification. The comments section of the *Notification of Drilling Waste Disposal Form* may indicate that a small volume of cuttings was mix-bury-covered or landspread on the wellsite. A separate *Notification of Drilling Waste Disposal Form* should have been completed and submitted, unless the wastes were disposed by landspray-while-drilling. If there is no separate notification or note in the comments section, the volume of cuttings can be calculated using the calculation in Section 1.3 of the Option 1 checklist. If the total volume of cuttings is >50m^3 and no supporting disposal information is available, Compliance Option Three is required. A calculation is provided in the checklist for estimating the volume of cuttings if the volume is not known.

When well sites have been re-entered or where another well has been drilled on the site, all drilling waste disposals must be accounted for if the drilling fluids contained additives. *Directive 50* requires that the licensee develop an acceptable disposal plan that both the

licensee and appropriate regulator agree to before drilling wastes are mix-bury-covered on a site previously used for disposal. The licensee must have this disposal plan, and confirmation that it was followed, on file and make it available to Alberta Environment, if requested. If the plan or confirmation is not available, Compliance Option Two or Three is required.

Advanced gel chemical systems such as *potassium sulphate, potassium silicate, sodium silicate, or potassium formate* systems have potentially high salinity associated with them and therefore calculations (as outlined in Compliance Option Two) must be performed or a Phase 2 ESA conducted. Alternatively, post-disposal sampling results from a program conducted in compliance with an EUB approval is acceptable if the results indicate compliance with the salinity, hydrocarbon, and trace element guidelines specified in Compliance Option Three.

A number of drilling fluid additives are used to ensure the fluid properties are compatible with the geological conditions encountered during drilling. Some additives are known to be toxic and some additives contained elevated levels of trace metals. The *Notification of Drilling Waste Disposal* form should provide a list of all additives used in the drilling fluid system. If this information is not included in the *Notification of Drilling Waste Disposal* form, or is incomplete, then an additional mud/additive list must be referenced. The additives used in the drilling process must be identified and described (e.g chrome-free lignosulfonate, aldehyde-based bactericide, etc.) so that potential toxicity and trace metal exceedences can be evaluated. The Petroleum Services Association of Canada maintains a list of historic additives and will assist in identifying unknown additives. This service can be accessed at http://www.psac.ca.

For mix-bury-cover disposal, the *Notification of Drilling Waste Disposal Form* must indicate the calculated post-disposal chloride concentration. *Directive 50* allowed up to 2000 mg/kg of chlorides with a loading limit of 1600 kg/site. This chloride concentration is incompatible with the *Directive 50 Equivalent Salinity Guidelines* (See Compliance Option Three) and will not be accepted by Alberta Environment because the *Directive 50* value will not achieve equivalent land capability requirements for reclamation. If the post disposal chloride concentration entered on the Notification Form exceeds 800 mg/kg, a Phase 2 ESA is required.

2. Hydrocarbon & Toxicity Management

Directive 50 requires testing of the waste for hydrocarbons if a hydrocarbon-based drilling fluid was used, hydrocarbons were added to the fluid, or the well was a horizontal oil well. For wastes generated under these conditions, hydrocarbon test results must be listed on the *Notification of Drilling Waste Disposal* form. Hydrocarbon test results will not be required for other drilling wastes that failed the original Microtox test but passed the Microtox test after charcoal filtration. Hydrocarbon concentrations in the final soil-waste mix must not exceed the *Directive 50* requirement of 0.1% (dry weight basis) for land treatment on subsoil, landspreading, and mix-bury-cover or 0.5% (dry weight basis) for land treatment on topsoil. Laboratories may provide the wet weight hydrocarbon values on the analytical back-up data results but the calculations on the *Notification of Drilling Waste Disposal* form require the dry weight value. Wet weight values can be converted to dry weight using the moisture content of the drilling waste sample.

Additives that may have toxicity concerns include bactericides, corrosion inhibitors, defoamers, emulsifiers and de-emulsifiers, foaming agents, lubricants, polymer stabilizers and breakers, surfactants, and shale control inhibitors. *Directive 50* required Microtox testing when an additive was used in a concentration that exceeded the toxicity threshold. Information on the toxicity of additives is available from the Petroleum Services Association of Canada (http://www.psac.ca).

3. Metals (Trace Elements) Management

Drilling fluid additives may contain trace metals and, depending on the quantities used, the drilling waste disposal area may exceed the current Alberta remediation criteria for natural areas or agricultural land use. Metal sources of concern include, but are not limited to, the following:

- Zinc carbonate ($ZnCO_3$) is commonly used to remove H_2S if it is encountered during drilling. In some cases, $ZnCO_3$ is contaminated with cadmium. If the checklist indicates that a Phase 2 ESA sampling program is required to assess zinc concentrations, cadmium must also be measured.

- Barite ($BaSO_4$) is used to increase fluid density.

- Chrome lignosulphonates were commonly used as thinners at one time, but have been largely phased out.

Calculation Tables are provided for the most common metal additives. If any of these additives were used, the appropriate Calculation Table must be used to evaluate the need for a Phase 2 ESA. If other trace metals specified in *Directive 50* were added to the drilling fluid in excess of the analytical thresholds in Section 3 or 5 of *Directive 50*, analytical data and the application rate (land treatment, landspreading, landspraying and landspray-while-drilling) or the maximum applied quantity (mix-bury-cover) must be available. If the information is not available or the application rate or maximum applied quantity exceeds *Directive 50* requirements, a Phase 2 ESA must be conducted.

Compliance Option 1 - Drilling Waste Disposal Assessment Checklist

If any response to the checklist questions leads to a Phase 2 ESA requirement, an environmental site assessment must be conducted in accordance with Compliance Option Three. If insufficient information is available to allow completion of the Compliance Option One checklist, Compliance Option Two or a Phase 2 ESA must be completed.

1. General Disposal and Drilling Fluid Information:
If some or all of the drilling waste was managed on-site (on the wellsite) or at a landtreatment area or a remote sump, then the checklist must be completed. In some cases, the drilling waste may have been managed at a remote sump/site that is not linked to the wellsite and as such a separate reclamation certificate may have been or need to be applied for at that separate location. If the remote sump or land treatment area is linked to the wellsite, proceed with the checklist for the remote sump or land treatment area. Where remote sumps are associated with multiple disposals managed in separate cells complete one checklist per disposal. Otherwise, complete one checklist by combining the information from all notification forms.

Section 1.0 to 1.3 must be completed for all disposals. The remaining sections do not need to be completed for wastes disposed of by the following methods:

a) If drilling waste was managed at an EUB or AENV approved waste management facility, indicate this using the appropriate checkbox below and list the supporting documentation (e.g. waste manifests, truck tickets, invoices, Alberta Oilfield Waste Management Form) under Reference Documents.

b) If the waste was disposed at an off-site location by landspraying or landspray-while-drilling (LWD) and the *Notification of Drilling Waste Disposal* form indicates the disposal method and location.

The notification form will indicate the type of drilling fluid system used. Water-based drilling fluids can be described in numerous ways for example; gel chem, floc water, fresh water gel, gypsum water, nitrate gypsum water, etc.

1.0 Well Information: Unique Identifier (UI) _____
Spud Date _____
Well Depth _____

1.1 Disposal Method (Check all that apply):

On-site
- ☐ Mix-bury-cover
- ☐ Landspread
- ☐ Land Treatment

Remote Site
- ☐ Mix-bury-cover
- ☐ Landspread
- ☐ Land Treament

Off-site
- ☐ Landspray-while-drilling
- ☐ Landspray
- ☐ Pumpoff
- ☐ Disposal on Licence of Occupation (Public Land only)
- ☐ Land Fill/Waste Management Facility

☐ Other, specify: _____

	Yes	No
1.2 Was the well re-entered or another well drilled on the same site using fluids containing drilling fluid additives?	☐	☐
If yes, were the disposal areas separate from one another?	☐ Drilling waste information must be evaluated for each disposal	☐
If the disposal areas were not separate, is documentation available to show that a disposal plan was followed that was agreed to by the licensee and the regulator?	☐ Disposal plan and confirmatory information must be retained on file and provided to Alberta Environment upon request.	☐ Compliance Option Two or Three required
1.3 Were cuttings or solids disposed of on-site that were associated with off-site waste disposal by LWD or landspraying?	☐	☐
If Yes, is separate analytical information or unique notification available?	☐	☐
If separate information or notification is not available, is the known volume (include references in Reference Documents) or estimated volume of waste disposed of on-site less than 50 m^3?	☐	☐ Phase 2 required
If the volume of cuttings or solids disposed of on-site is unknown, estimate the volume using following calculation and enter the data and results at right*: $V_C = V_T - V_{OFF}$ Where: V_C = Volume of cuttings or solids on-site (m^3) V_{OFF} = Volume of cuttings or solids disposed of off-site (m^3) V_T = Total volume of cuttings or solids (m^3) and: $V_T = \left(\frac{WDm}{2000}\right)^2 \times 3.14 \times WDp \times 1.2$ Where: WDm = Well diameter (mm) WDp = Well Depth (m) * If different hole sections have different diameters, V_C may be calculated for each section separately. Provide the data and result for each section at right or as an attachment.	Enter data below: V_C = _____ (m) V_T = _____ (m) V_{OFF} = _____ (m^3) WDm = _____ (mm) WDp = _____ (m)	

	Yes	No
1.4 Were water-based drilling fluids used (gel chemical drilling fluid system)?	☐	☐
If Yes, were all or part of the wastes disposed of on-site?	☐	☐
1.5 Was the drilling fluid described as an advanced gel chemical system such as the following: *potassium sulphate, potassium silicate, sodium silicate, or potassium formate*?	☐	☐
If Yes, were all or part of the wastes disposed of on-site?	☐	☐
If wastes were disposed of on-site, was the disposal done in compliance with an approval from the EUB?	☐ Approval and post-disposal sampling results must be retained on file and provided to Alberta Environment upon request.	☐ Compliance Option Two or Three Required
1.6 Is a mud list available and can all the additives on the mud list be identified and described? Record the additives and their description (e.g., chrome-free lignosulfonate, aldehyde-based bactericide, etc.) on the attached form.	☐	☐ Phase 2 required
1.7 For mix-bury-cover disposal, was calculated or measured post-disposal chloride concentration 800 mg/kg or less?	☐	☐ Phase 2 required
1.8 Was a remote site used?	☐	☐
If, Yes, is the remote site included in this reclamation application?	☐	☐
If not included, is the remote site a multi-well disposal location?	☐ In Comments section, indicate which well the remote site will be linked with for the purposes of reclamation	☐ Single well remote disposal site must be included with reclamation certificate application, unless it already has received a Reclamation Certificate.

2. Hydrocarbon & Toxicity Management

If hydrocarbon based drilling fluids were used (i.e. diesel inverts, synthetic or mineral oil systems) or hydrocarbons were added to the drilling fluid or the well is an horizontal oil well then it must be demonstrated that the resulting drilling waste was handled appropriately as per *Directive 50* or *Directive 58*. In most cases, if hydrocarbons were added to the system or if the well was a horizontal oil well it is still possible to dispose of the resulting drilling waste on the location and remain within allowable disposal limits but hydrocarbon testing and toxicity testing must have been conducted and documented on the notification form.

	Yes	No
2.1 Were hydrocarbon-based drilling fluids used or were hydrocarbons added to the drilling fluid or was the well a horizontal oil well?	☐	☐
If Yes, is documentation available showing that the wastes were disposed of in a manner consistent with *Directive 50* (1996) or *Directive 58?*	☐	☐ Phase 2 required
2.2 If hydrocarbon was present, is the predicted post-disposal hydrocarbon concentration at or below the appropriate guideline? (subsoil: 0.1%, topsoil: 0.5%)?	☐	☐ Phase 2 required
2.3 Was a Microtox test required as indicated on the disposal notification form?	☐	☐
If Yes, did the waste pass the Microtox requirements as outlined in *Directive 50* (waste must pass either the original or charcoal Microtox)?	☐	☐
If the waste failed the Microtox test (i.e., Microtox EC50 (15) original and Microtox EC50 (15) charcoal treated, reading at 15 minutes < 75%) is there evidence that demonstrates the waste was treated to remove toxicity and retested or disposed of as per *Directive 58* (i.e., appropriately approved waste management facility)?	☐	☐ Phase 2 required

3. Metals (Trace Elements) Management

Some drilling fluids contain trace metals and other toxic compounds. Metal-containing additives that have been or are being used include barite ($BaSO_4$), zinc carbonate ($ZnCO_3$), and chrome-based thinners. If these additives were used, the attached calculation tables must be completed and the results used to determine if a Phase 2 ESA is required.

	Yes	No
3.1 Was barite added to the drilling fluid? If Yes, did it meet the requirements specified in the attached metal calculation table?	☐ ☐ Show calculation on attached form	☐ ☐ Phase 2 required
3.2 Was zinc carbonate added to the drilling fluid? If Yes, did it meet the requirements specified in the attached metal calculation table?	☐ ☐ Show calculation on attached form	☐ ☐ Phase 2 required (Cadmium analysis will also be required.)
3.3 Were chrome-based thinners added to the drilling fluid? If Yes, did it meet the requirements specified in the attached metal calculation table?	☐ ☐ Show calculation on attached form	☐ ☐ Phase 2 required
3.4 Were any other metals added that triggered testing required by Section 3 or 5 of *Directive 50*? If Yes, are waste analytical data and application rates (land treatment, landspreading) or maximum application (mix-bury-cover) available? If above data are available, did the application rate or maximum application meet *Directive 50* requirements?	☐ ☐ ☐	☐ ☐ Phase 2 required ☐ Phase 2 required

Mud Additives (Attach additional pages if necessary.)

Product Name	Amount Used (units)	Brief Description of Product

Reference Documents (List all source documents used in the completion of this checklist. Attach additional pages if necessary. Documents must be supplied to Alberta Environment, if requested.)

Comments (Please provide any additional comments relevant to the decision process within the checklist. Attach additional pages if necessary.)

C. COMPLIANCE OPTION TWO

Compliance Option Two requires submission of the completed Compliance Option Two Checklist and accompanying Calculation Tables (attached) confirming that the specified requirements have been met. This option may be used when a *Directive 50 Notification of Drilling Waste Disposal* form is incomplete or not available, and/or an advanced gel chemical drilling fluid system was used and disposed on-site.

The Checklist and Calculation Tables will indicate if Compliance Option Two is acceptable for a site or whether a Phase 2 ESA is necessary. If no information or insufficient information is available to allow completion of either a Compliance Option One or Option Two checklist, a Phase 2 ESA must be completed where the waste disposal occurred. If the checklist indicates that a Phase 2 ESA is required and the disposal location is unknown, the Phase 2 ESA must be undertaken on the wellsite.

Background information is provided below to guide the completion of the Compliance Option Two checklist.

1. General Disposal and Drilling Fluid Information

There are various sources of information pertaining to the drilling activities on-site, including the *Directive 50 Notification of Drilling Waste Disposal* form, Tour Reports, daily drilling records, well files, contractor invoices and other information sources.

The records review may indicate the type of drilling fluids used (e.g., gel chem, advanced gel chem, salt, or hydrocarbon-based systems). If the type of mud system cannot be determined, a Phase 2 ESA is required. The records review must identify and describe the additives that were added to the drilling fluid system, and quantity (i.e., number of sacks or pails) of each additive. If the well licensee cannot identify and describe the additives and the quantity used, a Phase 2 ESA is required.

If an advanced gel chem or salt- or hydrocarbon-based system was used, the drilling waste must be handled appropriately as per *Directive 50* and/or *Directive 58*. If drilling waste was disposed at an approved waste management facility, proof of this disposition (e.g. manifests, truck tickets, invoices, Alberta Oilfield Waste Form, etc.) must be listed as Reference Documents on the checklist. Reference documents must be submitted to Alberta Environment, if requested. If the well licensee does not have documentation verifying waste disposition, a Phase 2 ESA is required.

When well sites have been re-entered or where another well has been drilled on the site, all drilling waste disposals must be accounted for if the drilling fluids contained additives. If the drilling wastes were disposed of in separate areas, a Compliance Option Two checklist must be completed for each disposal. If the drilling wastes were disposed of in the same area, the waste information should be combined and used to fill out a single checklist.

2. Hydrocarbon & Toxicity Management

Wastes from hydrocarbon-based fluids must be disposed of in accordance with *Directive 50* or taken to an EUB or AENV approved waste management facility. Drilling wastes taken to an approved waste management facility are subject to the tracking, characterization, and classification requirements under *Directive 58* and subsequent updates to it. On- or off-lease disposals by land treatment must have post-disposal sampling information and analytical data

demonstrating compliance with the requirements of *Directive 50* and the land treatment approval. In addition, land treatment sites remote to the wellsite require reclamation certification. Alternative disposal methods must have information demonstrating compliance with the EUB approval.

Directive 50 requires testing of the waste for hydrocarbons if they are intentionally or inadvertently added to the drilling fluids. Under *Directive 50*, hydrocarbon concentration in the final soil waste mix must not exceed 0.1% (dry weight basis) for land treatment on subsoil, landspreading, and mix-bury cover or 0.5% (dry weight basis) for land treatment on topsoil. Alberta Environment will accept existing file information showing that these endpoints were met in the final soil-waste mix. Laboratories may provide the wet weight hydrocarbon values in the analytical results but the calculations on the *Notification of Drilling Waste Disposal* form require the dry weight value. Wet weight values can be converted to dry weight using the moisture content of the drilling waste sample.

If drilling waste was disposed at an EUB or AENV approved waste management facility, documentation verifying use of the facility (e.g., manifests, truck tickets, invoices, Alberta Oilfield Waste Management Form) must be listed as Reference Documents on the checklist. Reference documents must be submitted to Alberta Environment, if requested. If the well licensee does not have proof of the drilling waste disposition, a Phase 2 ESA is required.

Hydrocarbon systems, such as diesel inverts, contain high hydrocarbon concentrations. If waste from hydrocarbon-based systems was disposed of on-site, a Phase 2 ESA under Compliance Option Three is required. Other drilling fluids may contain lower hydrocarbon concentrations resulting from hydrocarbon additives or contamination from the formation. Risk of formation fluids entering the waste are greater for horizontal oil wells and underbalanced drilling techniques. The well licensee must indicate if a well was classified as a horizontal oil well or whether underbalanced drilling was used.

A flow or kick may introduce produced fluids (hydrocarbons or salts) into the drilling fluids. If any of these actions have occurred, documentation must be available to demonstrate that the produced fluids were segregated from the drilling system (i.e., tanked or returned to tank trucks) and managed in accordance with *Directive 50* or *Directive 58*.

Drill stem test returns may also introduce hydrocarbons into drilling waste, unless the returns are segregated from the drilling system (i.e., tanked or returned to tank trucks) and managed in accordance with *Directive 50* or *Directive 58*. If this cannot be confirmed, disposal of the returns in the sump must be assumed. Calculations are provided to estimate their impact on the drilling waste. If insufficient information is available to complete the calculations, a Phase 2 ESA must be completed.

A number of drilling fluid additives are used to ensure the fluid properties are compatible with the geological conditions encountered during drilling. Additives that may have toxicity concerns include bactericides, corrosion inhibitors, defoamers, emulsifiers and de-emulsifiers, foaming agents, lubricants, polymer stabilizers and breakers, surfactants, and shale control inhibitors. Information on the toxicity of additives is available from the Petroleum Services Association of Canada. The additives used in the drilling process must be identified and described (e.g., chrome-free lignosulfonate, aldehyde-based bactericide, etc.) so that potential toxicity and trace metal exceedances can be evaluated. The Petroleum Services Association of Canada also maintains a list of historic additives and will assist in identifying unknown additives. Additive information can be accessed at http://www.psac.ca.

3. Metals (Trace Elements) Management

Drilling fluid additives may contain trace metals and depending on the quantities used, the drilling waste disposal area may exceed the current Alberta remediation guidelines for natural areas of agricultural land use. Metal sources of concern include, but are not limited to, the following:

- Zinc carbonate ($ZnCO_3$) is commonly used to remove H_2S if it is encountered during drilling. In some cases, $ZnCO_3$ is contaminated with cadmium. If the checklist indicates that a Phase 2 ESA sampling program is required to assess zinc concentrations, cadmium must also be measured.

- Barite ($BaSO_4$) is used to increase fluid density.

- Chrome lignosulphonates were commonly used as thinners at one time, but have been largely phased out.

Calculation Tables are provided for the most common metal additives. If any of these additives were used, the Calculation Table for the appropriate metal must be used to evaluate the need for a Phase 2 ESA. If other trace metals specified in *Directive 50* were added to the drilling fluid in excess of the *Directive 50* (Section 3 or 5) analysis thresholds analytical data and the application rate (land treatment, landspreading, landspraying and landspray-while-drilling) or the maximum applied quantity (mix-bury-cover) must be available. If the information is not available or the application rate or maximum applied quantity exceeded *Directive 50* requirements, a Phase 2 ESA must be conducted.

4. Salinity Management

Salts or salt generating additives can be classified as sodium salts, calcium salts, potassium salts and nitrogen salts. Within each classification, there are several individual compounds, as listed in Appendix A. The Salt Calculation Table must be used to evaluate the potential salinity of the waste. If the drilling waste does not meet the targets specified in the Salt Calculation Table, a Phase 2 ESA is required.

Salt zones can be encountered during drilling and contaminate drilling waste. The daily drilling reports, Tour Reports and/or other drilling records will indicate if a salt zone was encountered during drilling. A stratigraphic correlation chart showing salt formations in Alberta is also available from geological testing laboratories. If drilling occurred in a salt zone, or a flow or kick occurred, documentation must be available to demonstrate that the resulting drilling waste was appropriately treated or disposed of in accordance with *Directive 50* or *Directive 58*. If the well licensee cannot provide this information, a Phase 2 ESA is required.

Drill stem test returns may also introduce saline produced water into drilling waste, unless the returns are segregated from the drilling system (i.e., tanked or returned to tank trucks) and managed in accordance with *Directive 50* or *Directive 58*. If this cannot be confirmed, disposal of the returns in the sump must be assumed. Calculations are provided to estimate their impact on the drilling waste. If insufficient information is available to complete the calculations, a Phase 2 ESA must be completed.

Compliance Option 2 - Drilling Waste Disposal Assessment Checklist

If any response to the checklist questions leads to a Phase 2 ESA requirement or there is insufficient information to complete the Compliance Option Two Checklist, a Phase 2 ESA must be conducted in accordance with Compliance Option Three.

1. General Disposal and Drilling Fluid Information:
The well licensee should be able to review various sources of information pertaining to the drilling activities on-site. Many information sources, other than the *Notification of Drilling Waste Disposal* form from *Directive 50*, can be reviewed for information relating to the drilling waste disposal and drilling fluid systems. These can include Tour Reports, daily drilling records, well files, and contractor invoices.

1.0 Well Information: Unique Identifier (UI) _____
Spud Date _____
Well Depth _____

1.1 Disposal Method (if known)*: _____
* If waste was disposed at an EUB or AENV approved facility, list supporting documentation under Reference Documents.

1.2 Disposal Location (if known)** _____
** If checklist indicates that a Phase 2 ESA is required, it must be undertaken at the disposal location. If the disposal location is unknown, the Phase 2 ESA must be undertaken at the wellsite.

For the purpose of this form: if the disposal method and/or location remains unknown after all available information sources have been checked, the drilling waste disposal location is assumed to be onsite.

	Yes	No
1.3 Was the well re-entered or another well drilled on the same site using fluids containing drilling fluid additives?	☐	☐
If yes, were the disposal areas separate from one another?	☐ Drilling waste information must be evaluated for each disposal.	☐ Drilling waste information must be evaluated by combining the combined drilling fluid additives and well depths. If drilling waste information is missing or incomplete for one or both wells, a Phase 2 is required.

	Yes	No
1.4 Was a remote site used?	☐	☐
If, Yes, is the remote site included in this reclamation application?	☐	☐
If not included, is the remote site a multi-well disposal location?	☐ In Comments section, indicate which well the remote site will be linked with for the purposes of reclamation	☐ Single well remote disposal site must be included with reclamation certificate application, unless it already has received a Reclamation Certificate.
1.5 Has the well licensee reviewed the Daily Drilling Records and other available drilling documentation?	☐	☐ Phase 2 required
1.6 Can it be determined from the available records what type of drilling fluid system was used?	☐	☐ Phase 2 required
1.7 Were water-based drilling fluids used for all sections (i.e., gel chemical drilling fluid systems)?	☐	☐
If No, is there evidence that demonstrates the non water-based wastes were disposed of in a manner consistent with *Directive 50* or *Directive 58* (i.e., appropriately approved waste management facility)?	☐	☐ Phase 2 required
1.8 Is a mud list available?	☐	☐ Phase 2 required
If Yes, can all the additives on the mud list be identified and described? Record the additives and their description (e.g., chrome-free lignosulfonate, aldehyde-based bactericide, etc.) on the attached form.	☐	☐ Phase 2 required

	Yes	No
1.9 Do the Daily Drilling Records show evidence of a flow or kick that may have resulted in the introduction of produced fluids (i.e., hydrocarbons or salts) into the drilling fluids?	☐	☐
If Yes, is there information/documentation available to demonstrate that they were appropriately treated or disposed of as per *Directive 50* or *Directive 58* (i.e., approved waste management facility)?	☐	☐ Phase 2 required
1.10 Do the Daily Drilling Records show evidence of returned drill stem test fluids containing salt or oil?	☐	☐
If Yes, is there information/documentation available to demonstrate that they were appropriately treated or disposed of as per *Directive 50* or *Directive 58* (i.e., approved waste management facility)?	☐	☐
If treatment or disposal as per *Directive 50* or *Directive 58* cannot be confirmed, is there sufficient information/documentation available to complete the DST calculations?	☐ Show calculation on attached form	☐ Phase 2 required

2. Hydrocarbon Management

	Yes	No
2.1 Was the well a horizontal oil well?	☐	☐
If Yes, is there evidence that wastes were disposed of in a manner consistent with *Directive 50* or *Directive 58* (i.e., approved waste management facility)?	☐	☐ Phase 2 required
2.2 Was the well drilled using under-balanced techniques?	☐	☐
If Yes, is there information/documentation available to demonstrate that the drilling wastes were disposed of in a manner consistent with *Directive 50* or *Directive 58* (i.e., approved waste management facility)?	☐	☐ Phase 2 required

	Yes	No
2.3 Was hydrocarbon added to the drilling fluid?	☐	☐
If Yes, was the hydrocarbon contaminated drilling waste disposed of in a manner consistent with *Directive 50* or *Directive 58* (i.e., approved waste management facility)?	☐	☐ Phase 2 required

3. Metals (Trace Elements) Management

	Yes	No
3.1 Was barite added to the drilling fluid?	☐	☐
If Yes, did it meet the requirements specified in the attached metal calculation table?	☐ Show calculation on attached form	☐ Phase 2 required
3.2 Was zinc carbonate added to the drilling fluid?	☐	☐
If Yes, did it meet the requirements specified in the attached metal calculation table?	☐ Show calculation on attached form	☐ Phase 2 required
3.3 Were chrome-based thinners added to the drilling fluid?	☐	☐
If Yes, did it meet the requirements specified in the attached metal calculation table?	☐ Show calculation on attached form	☐ Phase 2 required
3.4 Were any other additives used that would have triggered testing for metals under Section 3 or 5 of *Directive 50*?	☐	☐
If Yes, are waste analytical data and application rates (land treatment, landspreading) or maximum application (mix-bury-cover) available?	☐	☐ Phase 2 required
If above data are available, did the application rate or maximum application meet *Directive 50* requirements?	☐	☐ Phase 2 required

4. Salinity Management

	Yes	No
4.1 Does the water based drilling waste meet the requirements specified in the attached Salt Calculation Table?	☐ Show calculation on attached form	☐ Phase 2 required
4.2 Was a salt zone encountered during drilling?	☐	☐
If Yes, is there evidence that demonstrates the drilling wastes were disposed of in a manner consistent with *Directive 50* or *Directive 58* (i.e., appropriately approved waste management facility)?	☐	☐ Phase 2 required

Mud Additives (Attach additional pages if necessary.)

Product Name	Amount Used (units)	Brief Description of Product

Reference Documents (List all source documents used in the completion of this checklist. Attach additional pages if necessary. Documents must be supplied to Alberta Environment, if requested.)

Comments (Please provide any additional comments relevant to the decision process within the checklist. Attach additional pages if necessary.)

D. COMPLIANCE OPTION THREE

1. Phase 2 Environmental Site Assessments

Soil samples must be taken from within the drilling waste disposal area. The samples must be analyzed for all parameters of concern as identified by drilling records. Information can be obtained from Tour Reports, daily drilling records and company files. Where drilling records are not available, incomplete, or the composition of the additives is unknown, the samples must be analyzed for petroleum hydrocarbons, the trace elements specified in *Directive 50* plus barium, electrical conductivity (EC) and sodium adsorption ratio (SAR). The sampling densities specified below are minimum requirements. Where conditions indicate unusually high variability or disposal of high risk drilling fluids (e.g., diesel invert, high salinity fluids), assessors should increase sampling effort accordingly. *If the drilling waste disposal is unknown after all available sources have been checked, the Phase 2 ESA must be conducted onsite or at the likely drilling waste disposal location (ie. Remote sump) to confirm if drilling waste was disposed of at the subject location.*

If the Phase 2 ESA analytical data indicates that the drilling waste disposal area does not meet the guidelines described below, the drilling waste disposal area must be managed to achieve equivalent land capability in order to receive a Reclamation Certificate. Confirmatory sampling requirements in support of site closure will be site-specific and must be conducted by a qualified person.

(a) Sampling Requirements

The minimum sampling requirements below are for drilling waste disposal areas only. They must be used to characterize the disposal area after its location has been identified. The level of effort required to find the waste disposal area, as well as environmental site assessment requirements for other areas of the site (e.g. well centre, flare pits, spills, etc.), will be site-specific. The sampling requirements below are for characterizing known waste disposal areas.

Land Treated, Buried and/or Landspread Waste from up to 3 Single Wells

Note: These requirements also apply to areas of the lease receiving liquid waste during squeezing or dump and bail operations.

The minimum number of sampling locations from the disposal area will vary with well depth as follows:

Well Depth* (m)	Number of Sampling Locations
<1500	3
1500 to 2500	4
>2500	5

*If two or three wells have been combined, the sum of the individual well depths must be used.

Sampling locations (boreholes) must be arranged so that the entire drilling waste disposal area is represented. For each borehole, a sample that is representative of the waste or soil-waste mix zone must be submitted for laboratory analysis. This sample may be a composite made by combining subsamples from the same borehole. Waste or soil-waste mix samples must not contain cover or base material (Fig. 1). Samples must not combine material from more than one of the depth increments specified for the *Directive 50 Equivalent Salinity Guidelines* (below). For example, if the mix-bury-cover disposal area has only 0.9 m of cover, the top 0.10 m of the drilling waste disposal zone must be sampled separately.

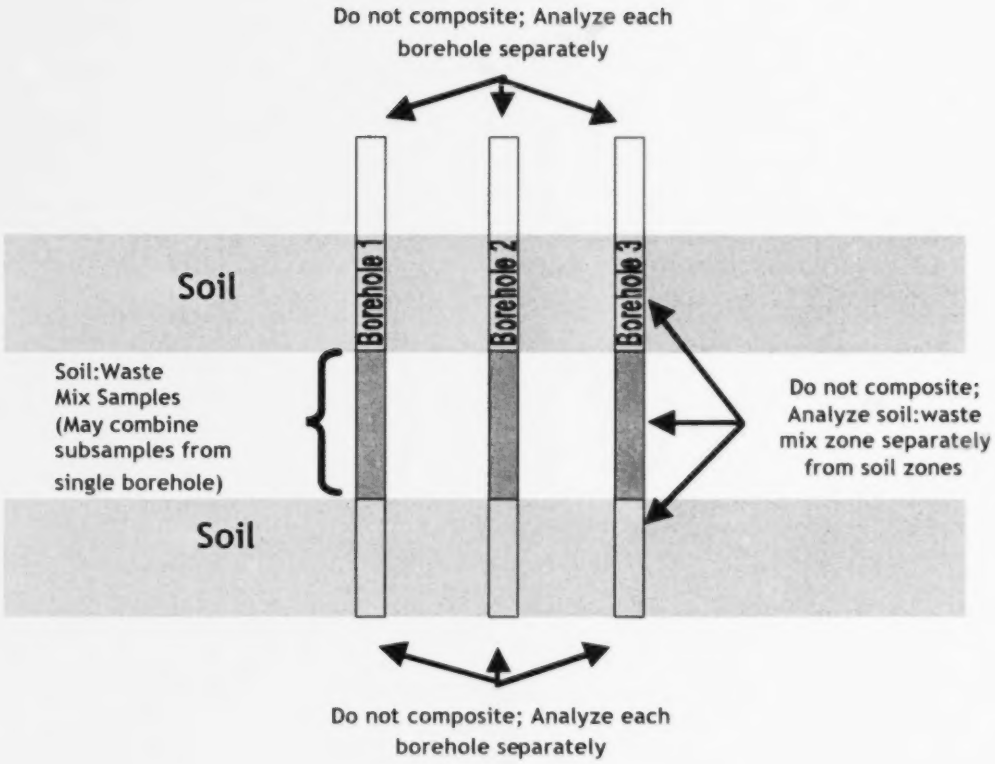
Do not composite; Analyze each borehole separately
Soil
Borehole 1
Borehole 2
Borehole 3
Soil:Waste Mix Samples (May combine subsamples from single borehole)
Do not composite; Analyze soil:waste mix zone separately from soil zones
Soil
Do not composite; Analyze each borehole separately

Figure 1. Minimum sampling protocol for well depth < 1500m.

Samples from different sampling locations or boreholes must not be combined (Fig. 1). Borehole logs must show that the borehole extended to at least 1 metre below the base of the waste zone and must characterize the entire borehole depth. The site assessment must indicate whether permeable material is present within 1 metre of the base of the soil-waste mix. Permeable material is defined as having a median grain size greater than 75 microns. One or more control samples are required for comparison of background salinity levels unless the disposal area meets the *G50 Equivalent Salinity Guidelines* (below). Control samples may also be useful for evaluating naturally elevated metal concentrations and other anomalies. If possible, control samples must be taken from an undisturbed profile in similar landscape positions and at the same depths as the waste material. Soil at the control locations must be representative of the soil found on the site and must not be contaminated. The information submitted to Alberta Environment must include the analytical results, sampling locations and depth, and drill logs/soil profile descriptions that show material changes with depth.

Land Treatment, Remote Multi-well Disposal Area, or On-site Disposal from More than 3 Single Wells

These areas must be delineated (e.g., visual identification of drilling waste, EM surveys, etc.) and a site-specific sampling and analytical program developed that is based on disposal area or volume.

Analysis of Samples

Samples must be analyzed for the parameters of concern identified by the Compliance Option One or Two Checklist. Electrical conductivity (EC), sodium adsorption ratio (SAR), trace elements, and petroleum hydrocarbons must be measured if available information was not sufficient to complete the Checklists. EC and SAR must be measured in a saturated paste extract. Trace elements must be measured after extraction by strong acid digest, except boron, which must be measured in a hot water extract. Analysis of petroleum hydrocarbons conducted after January 1, 2002 must comply with the *Reference Method for the Canada Wide Standard for Petroleum Hydrocarbons in Soil - Tier I Method.*

Analytical results must meet the guidelines specified below.

Salinity Guidelines

Directive 50 Equivalent Salinity Guidelines in the following table may be used as an alternative to the *Salt Contamination Assessment and Remediation Guidelines* (Alberta Environment 2001).

Directive 50 Equivalent Salinity Guidelines

Topsoil	EC of 2 dS/m, SAR of 6
Below topsoil to 1 metre	EC of 3 dS/m, SAR of 8
Below 1 metre	EC of 6 dS/m, SAR of 10

Directive 50 Equivalent Salinity Guidelines for topsoil must not be exceeded. Below topsoil, if receiving soil exceeds these guidelines because of naturally occurring salt, an increase of 1 dS/m for EC and 1 unit for SAR above pre-disposal receiving soil background will be accepted. Alternatively, compliance with Alberta Environment's *Salt Contamination Assessment and Remediation Guidelines* (2001) is accepted.

Use of the *Directive 50 Equivalent Salinity Guidelines* assumes compliance with other *Directive 50* requirements. In particular, for the mix-bury-cover disposal method, the base of the soil-waste mix must be at least 1 metre above a layer of permeable material. Permeable material is defined as having a median grain size greater than 75 microns. Every effort should be made to ensure that a minimum of 1 metre of clean subsoil is maintained over the soil-waste mix before topsoil is replaced.

The purpose of using clean subsoil is to ensure that the root zone remains free of contamination. EC and SAR levels of the subsoil used for capping must meet the above guidelines. In many soils this means that some or all of the subsoil excavated during sump construction or cut-and-fill operations is not suitable capping material. Sites that do not meet the above guidelines because naturally saline soils have been mixed into the capping material must be managed to meet equivalent land capability in order to be eligible for a Reclamation Certificate.

Hydrocarbon and Trace Element Guidelines

Petroleum hydrocarbon and trace element concentrations must comply with the current Alberta remediation guidelines.

File information confirming that mineral oil and grease concentrations in the soil-waste mix were 0.1% (dry weight) or less in subsoil or 0.5% (dry weight) or less in topsoil will be accepted in lieu of current site assessment data for hydrocarbons.

Metal Calculations for Compliance Options One and Two

Note: Different default mix ratios are provided for well depth-based calculation alternatives depending on whether the well was drilled before or after October 22, 1996. The current *Directive 50, Drilling Waste Management*, which was issued by the Energy and Utilities Board on this date, increased the minimum mix ratio requirement from 1:1 to 3:1.

Barite:

Directions: Fill in the number of sacks and adjust for sack weight if different than 40 kg. Enter the Well Depth and divide the Total Number of Sacks by the Well Depth. Divide this value by the Mix Ratio. Enter the result as Sacks per Metre. This value must be less than or equal to **0.070**. If the value exceeds the objective, a Phase 2 ESA must be conducted.

Total Number of Sacks (40 kg/sack*)		Well Depth (m)		Mix Ratio**		Sacks per Metre
	÷		÷		=	

* Sack weight may be adjusted by dividing the number of sacks by 40 and multiplying by the actual sack weight in kilograms. This value should be entered as the number of sacks.

** Enter the number of parts of soil mixed with one part of waste. For example, for a 3:1 mix ratio (3 parts soil to 1 part waste) enter "3". If this value is not known, enter **1** for wells drilled before October 22 1996, or **3** for wells drilled on or after this date.

Zinc Carbonate:

Alternative 1:

If waste zinc concentration, mix ratio and waste dry bulk density data are available, use the following calculator to estimate post-disposal zinc concentration.

Directions: Enter the total zinc concentration measured in the waste, the Waste Dry Bulk Density, and Mix Ratio in the appropriate cells. Multiply Waste Zinc Concentration by Waste Dry Bulk Density and divide the result by the Mix Ratio. Divide this value by 1500 then add 70. The result is the Post-Disposal Zinc Concentration. This value must be less than or equal to **200** mg/kg. If the value exceeds this objective, a Phase 2 ESA must be conducted.

Waste Zinc Concentration (mg/kg)		Waste Dry Bulk Density* (kg/m^3)		Mix Ratio**						Post-Disposal Zn Concentration (mg/kg)
	x		÷		÷	1500	+	70	=	

* Waste Dry Bulk Density = (Waste Specific Gravity - 1) x 1600

** Enter the number of parts of soil mixed with one part of waste. For example, for a 3:1 mix ratio (3 parts soil to 1 part waste) enter "3". If this value is not known, enter **1** for wells drilled before October 22 1996, or **3** for wells drilled on or after this date.

Alternative 2:

If the above data is not available use the following equation to calculate the number of sacks of zinc carbonate added per metre drilled.

Directions: Fill in the number of sacks and adjust for sack weight if different than 25 kg. Enter the Well Depth in metres and divide the Total Number of Sacks by the Well Depth. Divide this value by the Mix Ratio. Enter the result as Sacks per Metre. This value must be less than or equal to **0.0065**. If the value exceeds the objective, a Phase 2 ESA must be conducted.

Total Number of Sacks (25 kg/sack*)		Well Depth (m)		Mix Ratio**		Sacks per Metre
	÷		÷		=	

* Sack weight may be adjusted by dividing the number of sacks by 25 and multiplying by the actual sack weight in kilograms. This value should be entered as the number of sacks.

** Enter the number of parts of soil mixed with one part of waste. For example, for a 3:1 mix ratio (3 parts soil to 1 part waste) enter "3". If this value is not known, enter **1** for wells drilled before October 22 1996, or **3** for wells drilled on or after this date.

Chromium-based Thinner:

Alternative 1:

If waste chromium concentration and waste bulk density data are available, use the following calculator to estimate post-disposal chromium concentration.

Directions: Enter the total chromium concentration measured in the waste, the Waste Dry Bulk Density, and Mix Ratio in the appropriate cells. Multiply Waste Chromium Concentration by Waste Dry Bulk Density and divide the result by the Mix Ratio. Divide this value by 1500 then add 30. The result is the Post-Disposal Chromium Concentration. If this value is greater than **64** mg/kg, a Phase 2 ESA is required.

Waste Chromium Concentration (mg/kg)		Waste Dry Bulk Density* (kg/m^3)		Mix Ratio**						Post-Disposal Cr Concentration (mg/kg)
	x		÷		÷	1500	+	30	=	

* Waste Dry Bulk Density = (Waste Specific Gravity - 1) x 1600

** Enter the number of parts of soil mixed with one part of waste. For example, for a 3:1 mix ratio (3 parts soil to 1 part waste) enter "3". If this value is not known, enter **1** for wells drilled before October 22 1996, or **3** for wells drilled on or after this date.

Alternative 2:

If the above data is not available, use the following equation to calculate the number of sacks of chrome thinner added per metre drilled. If the number of sacks exceeds the limits below, a Phase 2 is required.

Directions: Fill in the number of sacks and adjust for sack weight if different than 25 kg. Enter the Well Depth and divide the Total Number of Sacks by the Well Depth. Divide this value by the Mix Ratio. Enter the result as Sacks per Metre. This value must be less than or equal to **0.020**. If the value exceeds the objective, a Phase 2 ESA must be conducted.

Total Number of Sacks (25 kg/sack*)		Well Depth (m)		Mix Ratio**		Sacks per Metre
	÷		÷		=	

* Sack weight may be adjusted by dividing the number of sacks by 25 and multiplying by the actual sack weight in kilograms. This value should be entered as the number of sacks.

** Enter the number of parts of soil mixed with one part of waste. For example, for a 3:1 mix ratio (3 parts soil to 1 part waste) enter "3". If this value is not known, enter **1** for wells drilled before October 22 1996, or **3** for wells drilled on or after this date.

Drill Stem Test Return Calculations for Compliance Option Two

Salinity:

Note: Either the resistivity or the chloride calculation must be completed. It is not necessary to complete both calculations. Resistivity data should be used when available. If resistivity is not available, the chloride calculation should be used. If the volume is specified but neither chloride nor resistivity is available, use the default concentration in the chloride calculation. If no volume is available, a Phase 2 is required.

Alternative 1: Resistivity

Directions: Fill in the volume of each drill stem test return (add more lines as necessary) and multiply by 0.28. Divide this value by the measured resistivity and enter the result as Number of Sacks. Add up the total number of sacks and enter this value in the salinity calculation at the appropriate line.

Volume of Returns (m^3)*				Resistivity (Ohms)		Number of Sacks
	x	0.28	÷		=	
	x	0.28	÷		=	
	x	0.28	÷		=	
	x	0.28	÷		=	
				Total number of sacks	=	

* Volume of returns may be calculated by the following equation:

$$V_R = \left(\frac{ID}{2000}\right)^2 \times 3.14 \times L_{dst}$$

Where:

V_R = Volume of Drill Stem Test Returns

ID = Inner diameter of pipe (mm)

L_{dst} = Length of Drill Stem Test Return (m)

Alternative 2: Chloride

Directions: Fill in the volume of each drill stem test return (add more lines as necessary) and multiply by the chloride concentration. Divide this value by 7,600 and enter the result as Number of Sacks. Add up the total number of sacks and enter this value in the salinity calculation at the appropriate line.

Volume of Returns (m3)*		Chloride Concentration** (mg/L)				Number of Sacks
	x		÷	7600	=	
	x		÷	7600	=	
	x		÷	7600	=	
	x		÷	7600	=	
				Total number of sacks	=	

* Volume of returns may be calculated by the following equation:

$$V_R = \left(\frac{ID}{2000}\right)^2 \times 3.14 \times L_{dst}$$

Where:

V_R = Volume of Drill Stem Test Returns

ID = Inner diameter of pipe (mm)

L_{dst} = Length of Drill Stem Test Return (m)

**If chloride concentration is not specified, use 350,000 mg/L.

Hydrocarbons

Directions: Fill in the volume of each drill stem test return (add more lines as necessary) and multiply by the oil concentration in the return. Enter this value as Volume of Oil. Add up the Total Volume of Oil and enter this value. Divide this value by 0.6 then divide by the well depth. Divide this value by the mix ratio. Enter the result as the Post-Disposal Oil Concentration. This value must be less than 0.1% (dry weight) in subsoil or 0.5% (dry weight) in topsoil.

Volume of Returns* (m3)		Oil Content (%)**		Vol. of Oil								
	x		=					Well Depth (m)		Mix Ratio***		Post-Disposal Oil Concentration (%)
	x		=									
	x		=									
Total Volume of Oil			=		÷	0.6	÷		÷		=	

* Volume of returns may be calculated by the following equation:

$$V_R = \left(\frac{ID}{2000}\right)^2 \times 3.14 \times L_{dst}$$

Where:

V_R = Volume of Drill Stem Test Returns

ID = Inner diameter of pipe (mm)

L_{dst} = Length of Drill Stem Test Return (m)

** Actual measured oil concentration must be used if available. If only visual descriptions are available then use the following to estimate oil concentration:

Flecked = 5%

Emulsion = 25%

Oil or oil-cut mud= 100%

Do not include gas-cut mud or mud with no indication of oil.

*** Enter the number of parts of soil mixed with one part of waste. For example, for a 3:1 mix ratio (3 parts soil to 1 part waste) enter "3". If this value is not known, enter **1** for wells drilled before October 22 1996, or **3** for wells drilled on or after this date.

Salt Calculations for Option 2:

Alternative 1

If the volume of drilling waste is known, use the following calculator to determine the NaOH Equivalent Sacks per m^3 of waste. If this value is greater than **0.10**, a Phase 2 ESA is required.

Directions: Fill in the number of sacks and adjust for sack weight if different than 25 kg. For each additive, multiply the Number of Sacks by the NaOH Equivalency Factor and write the result in the NaOH Equivalent Sacks column. Sum all the entries in the NaOH Equivalent Sacks column and enter the result. Enter the Waste Volume and divide the Total NaOH Equivalent Sacks by the Waste Volume. Enter the result as Equivalent Sacks per m^3. This value must be less than **0.10**.

Additive	Number of Sacks (25 kg/sack*)		NaOH Equivalency Factor		NaOH Equivalent Sacks
Caustic Soda		X	1.00	=	
Soda Ash		X	0.75	=	
Sodium Chloride		X	0.68	=	
Sodium Bicarbonate		X	0.95	=	
Sodium Silicate		X	1.37	=	
Sodium acid pyrophosphate (SAPP)		X	0.22	=	
Calcium Chloride		X	0.72	=	
Calcium Nitrate		X	0.34	=	
Envirofloc		X	0.41	=	
Gypsum**		X	0.59	=	
Lime**		X	1.08	=	
** Maximum number of sacks = 0.02 x well depth (m)					
Potassium chloride		X	0.54	=	
Potassium sulphate		X	0.46	=	
Caustic potash		X	0.71	=	
Potassium formate		X	0.47	=	
Potassium silicate		X	0.32	=	
Potassium nitrate		X	0.40	=	
Diammonium phosphate		X	0.63	=	
Ammonium nitrate		X	0.57	=	
Ammonium sulphate		X	0.61	=	
Drill Stem Test Returns		X	0.68		
			Total NaOH Equivalent Sacks	=	
			Waste Volume (m^3)	÷	
			Equivalent Sacks per m^3	=	

* Sack weight may be adjusted by dividing the number of sacks by 25 and multiplying by the actual sack weight in kilograms. This value should be entered as the number of sacks.

** Note: Up to 0.02 sacks of gypsum and lime per metre of well depth should be counted with other salt additives. Gypsum and lime must be calculated separately. Because of the limited solubility of gypsum and lime, sacks in excess of this value need not be counted.

Alternative 2

If the volume of drilling waste is not known, use the following calculator to determine the NaOH Equivalent Sacks per metre of well depth. This value must be less than **0.026** for wells drilled before October 22 1996, or **0.035** for wells drilled on or after this date. If the value exceeds the target, a Phase 2 ESA must be conducted.

Directions: Fill in the number of sacks and adjust for sack weight if different than 25 kg. For each additive, multiply the Number of Sacks by the NaOH Equivalency Factor and write the result in the NaOH Equivalent Sacks column. Sum all the entries in the NaOH Equivalent Sacks column and enter the result. Enter the Well Depth and divide the Total NaOH Equivalent Sacks by the Well Depth. Enter the result as Equivalent Sacks per Metre.

Additive	Number of sacks (25 kg/sack*)		NaOH Equivalency Factor		NaOH Equivalent Sacks
Caustic Soda		X	1.00	=	
Soda Ash		X	0.75	=	
Sodium Chloride		X	0.68	=	
Sodium Bicarbonate		X	0.95	=	
Sodium Silicate		X	1.37	=	
Sodium acid pyrophosphate (SAPP)		X	0.22	=	
Calcium Chloride		X	0.72	=	
Calcium Nitrate		X	0.34	=	
Envirofloc		X	0.41	=	
Gypsum**		X	0.59	=	
Lime**		X	1.08	=	
** Maximum number of sacks = 0.02 x well depth (m)					
Potassium chloride		X	0.54	=	
Potassium sulphate		X	0.46	=	
Caustic potash		X	0.71	=	
Potassium formate		X	0.47	=	
Potassium silicate		X	0.32	=	
Potassium nitrate		X	0.40	=	
Diammonium phosphate		X	0.63	=	
Ammonium nitrate		X	0.57	=	
Ammonium sulphate		X	0.61	=	
Drill Stem Test Returns		X	0.68		
			Total NaOH Equivalent Sacks	=	
			Well Depth (m)	÷	
			Equivalent Sacks per Metre	=	

* Sack weight may be adjusted by dividing the number of sacks by 25 and multiplying by the actual sack weight in kilograms. This value should be entered as the number of sacks.

** Note: Up to 0.02 sacks of gypsum and lime per metre of well depth should be counted with other salt additives. Gypsum and lime must be calculated separately. Because of the limited solubility of gypsum and lime, sacks in excess of this value need not be counted.